



b's in Our Bonnet

(using B-hadrons to probe new physics)

Hal Evans

Columbia University

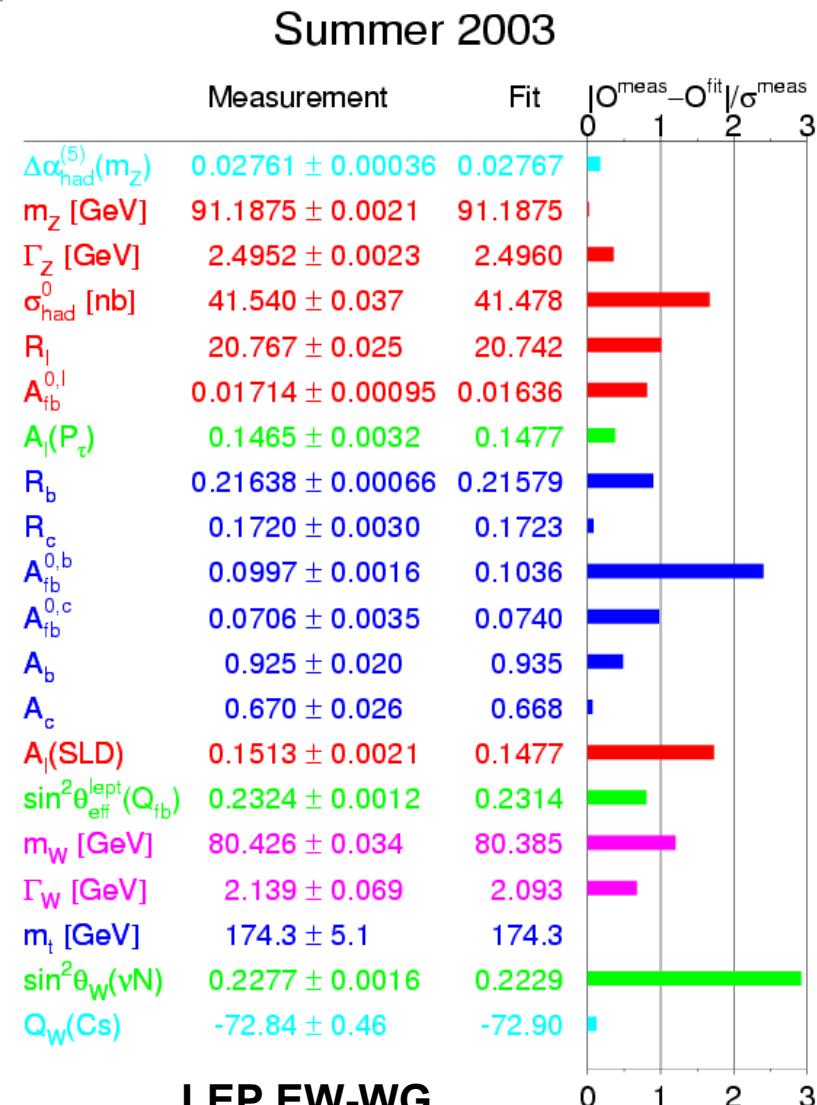
1. Why the b-Quark ? (broad goals of HEP)
 2. Why at DØ ? (b-physics at hadron colliders)
 3. How Do You Do It ? (B_s mixing as an example)
 4. What Do You Get ? (where does it all fit in)



Standing on Solid Ground

Matter (fermions)	Chg [e]	Mass [MeV]		
Leptons				
ν_e	0	$O(<eV)$		
e	-1	0.5	105	1777
Quarks				
u	+2/3	1–5	1300	174300
d	-1/3	3–9	150	4.4

Force Carriers	Boson	Mass [GeV]	Strength
Gravity	G	0	10^{-39}
E-M	γ	0	10^{-2}
Weak	W^\pm	80.419	10^{-5}
	Z^0	91.1882	
Strong	g	0	$10^{-1} (M_Z)$
E-W Sym	H^0	>114	m_f^2





If it ain't Broke – Fix It !

Why Look Beyond the SM ?

- Has 19 arbitrary parameters
- Higgs Mass not stable to radiative corrections
 - $M_h^2 \sim M_{h0}^2 + \frac{\lambda}{4\pi^2} \Lambda^2 + \delta M_h^2$
 - $\Lambda \sim M_{\text{planck}}$ for no new phys
 - $M_h < 800 \text{ GeV}$
 \Rightarrow tuning to 10^{-16}
- No Motivation for EW Symmetry Breaking
- Does not include Gravity
 - * Why $M_{\text{pl}} \gg M_{\text{EW}}$?



Where Should We Look ?

Start with the BIG Questions

- 1. Why is there Mass ? EW Symmetry Breaking
- 2. Antimatter ? Weak vs Mass States & CPV
- 3. What about Matter ? understanding QCD

Look in New Places

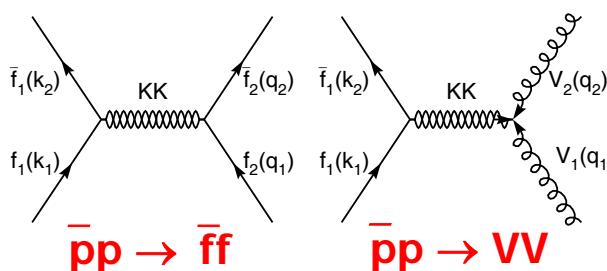
- Sparse Measurement \Rightarrow Lots of Options
- The Winning Candidate: EW Symmetry Breaking !
 - turns out to be related to question 2) as well



Lots of Ideas

There are lots of Ideas...

- **Dynamical Symmetry Breaking**
 - **Technicolor:**
 - * ~~running, walking, limping...~~
- **Supersymmetry (SUSY)**
 - GMSSM, SUGRA, R-Parity Violating
- **Large Extra Dimensions**
 - testable string theory!



- monojets
- single VB
- f,VB-pairs

- etc., etc., etc....

Standard Model Particle	S	Superpartners Sparticle	S
q_L, q_R	$\frac{1}{2}$	\tilde{q}_L, \tilde{q}_R	0
ℓ_L, ℓ_R	$\frac{1}{2}$	$\tilde{\ell}_L, \tilde{\ell}_R$	0
ν_L	$\frac{1}{2}$	$\tilde{\nu}_L$	0
W^\pm, Z^0, γ	1	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^\pm$	$\frac{1}{2}$
h^0, H^0, A^0, H^\pm	0	$\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_3^0, \tilde{\chi}_4^0$	$\frac{1}{2}$
g	1	\tilde{g}	$\frac{1}{2}$

MSSM: $M(h) < 135 \text{ GeV !!!}$

They all answer **some** questions

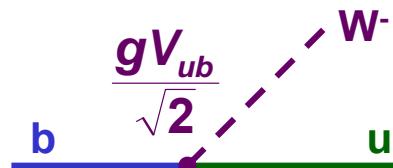
- Look like the SM at low E
- Differences only show up at
 - high Energy
 - small corr's to SM predictions



The Symmetry–Flavor Connection

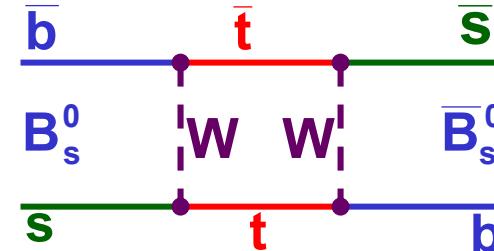
- The SM has a Lovely Plan for EW Sym Break & Mass
 - $L_Y = -\sum_{i,j=family} [\hat{y}_{ij}^e \bar{L}_L^i \phi E_R^j + \hat{y}_{ij}^d \bar{Q}_L^i \phi D_R^j + \hat{y}_{ij}^u \bar{Q}_L^i \phi U_R^j + h.c.]$
- SM Symmetries & Yukawa Couplings \Rightarrow Quark Mixing
 - $\hat{y}_{ij}^e, \hat{y}_{ij}^u$ (by convention) = real, diagonal
 - \hat{y}_{ij}^d = imag. comp's, non-diagonal
- Mixing (CKM) Matrix: V_{ij}
 - $L_Y = -\sum_i [y_i^u \bar{Q}_L^i \tilde{\phi} U_R^i + h.c.] - \sum_{i,j} [y_j^d \bar{Q}_L^i \phi V_{ij} D_R^j + h.c.]$
- EW Sym Breaking \Rightarrow Observed Flavor Structure

Family Changing Decays



H.Evans

Alberta Colloquium: 5-Feb-04



Mixing

6



Quarks are all mixed up !

Quark Weak \neq Mass Eigenstates
 \Rightarrow CKM Mixing Matrix

- 3 angles
- 1 complex phase \Rightarrow CP-violation
- Obs. CPV requires $m(q_i) \neq m(q_j)$

$$\text{Weak} \begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} \text{Mass}$$

Wolfenstein Parameterization

- Strength of CPV
 $J = A^2 \lambda^6 \eta \sim (7 \times 10^{-5}) \eta$

$$\begin{pmatrix} 1 - \frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

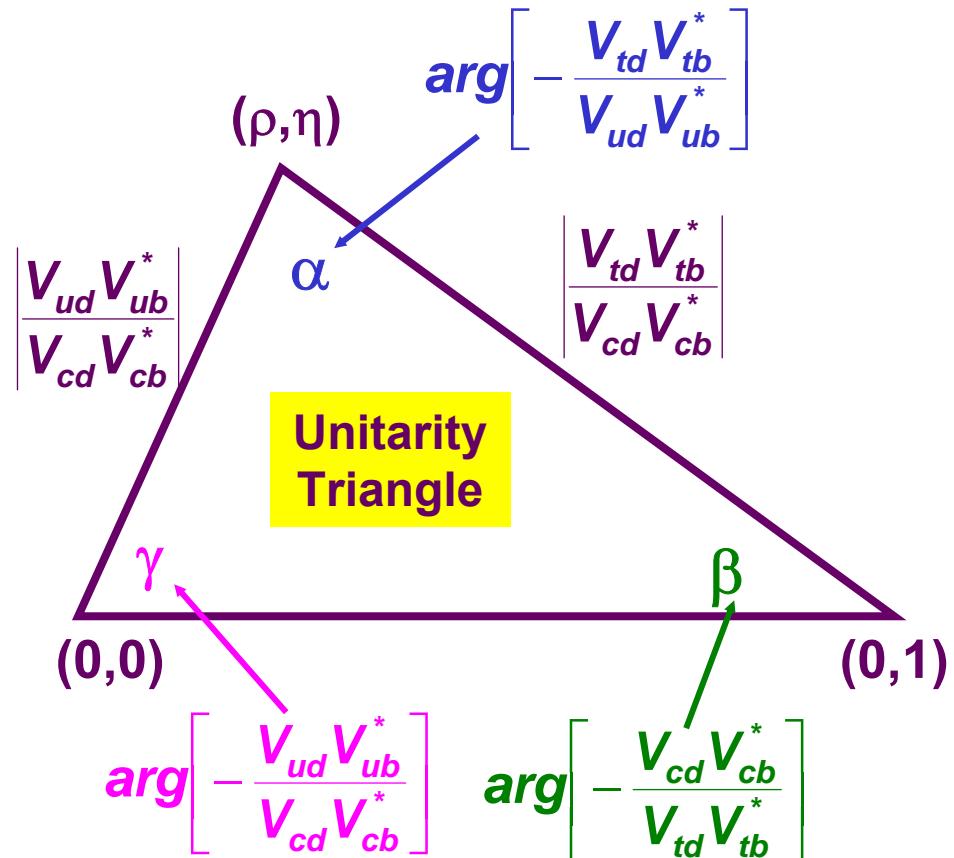


The Unitarity Triangle

Unitarity of $V_{CKM} \Rightarrow 6$ triangles:

- one has all sides \sim equal

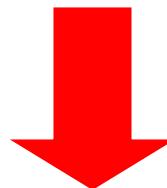
$$V_{ub} V_{ud}^* + V_{cb} V_{cd}^* + V_{tb} V_{td}^* = 0$$





Why is Flavor Promising (1)

The SM has a very Specific Flavor Sector:
Only one Higgs Doublet



1. FCNC's suppressed
2. Universal Charged Current
3. V_{CKM} is Unitary
4. 1 Parameter describes strength of all CP Violation



Why is Flavor Promising (2)

- Other Models much less restricted than SM
- But – strong constraints from existing measurements in K and B sectors
 - 3rd generation least constrained

Use Flavor to Select Among Classes of Models:

1. Most Generic Models
 - flavor physics is an input to model building
 2. Flavor Suppress. in 1st two gen's
 - large effects in B-systems
 3. Flavor Suppress. in u-sector
 - large effects in charm
 4. Generic Flavor Suppression
 - large effects in flavor physics
 5. New Physics is Flavor Blind (MFV)
 - small effects in flavor physics
- Example
- already ruled out
- Randall-Sundrum
- SUSY w/ alignment
- Split Fermions in FED
- GMSB

Yuval Grossman: Lepton-Photon 2003



Beauty as a Probe

B-Physics is a Good Place to Probe EW Sym. Breaking

- measurable unitarity triangle
- QCD corrections to predictions small

1. Look for Modifications to Couplings

- Different EW Sym. Breaking Struct. \Rightarrow Different Couplings
- Most Interesting Channels = Rare or Zero in SM

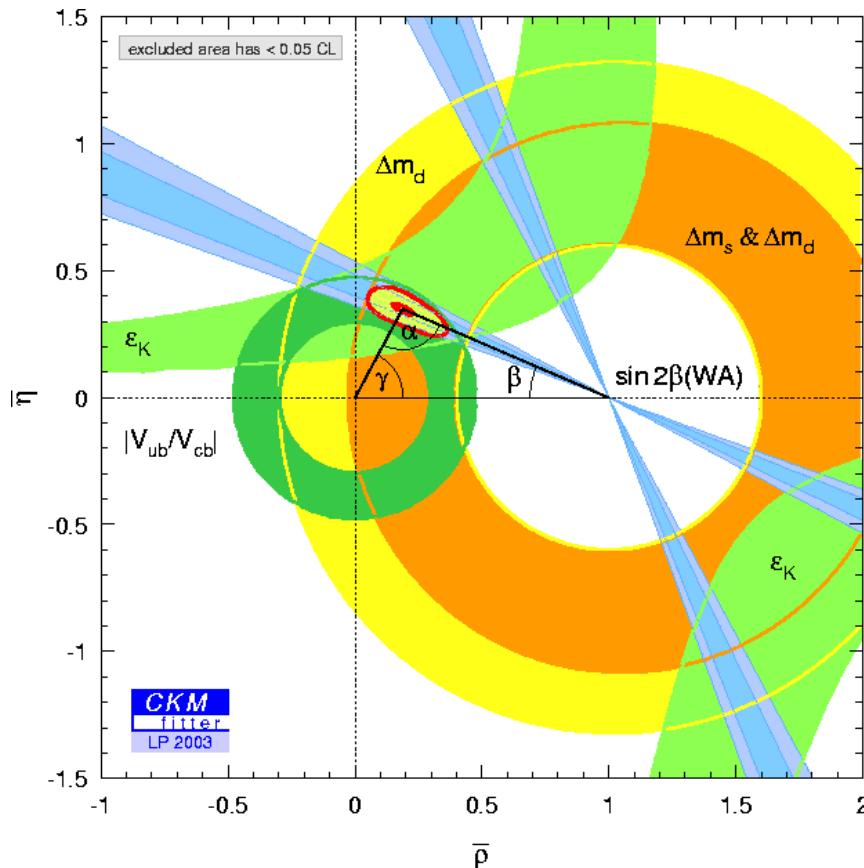
2. Check Consistency of CKM Picture

- Many meas's sensitive to CKM magnitudes & phases
 - * Rates, Mixing \Rightarrow Magnitudes (sides of U.T.)
 - * CPV Asymmetries \Rightarrow Phase(angles of U.T.)
 - * general measurement can depend on several U.T. param's
- These should all form a single triangle if the SM is correct
 - * other models predict different relationships

But Wait, There's More – QCD !

- b-production, spectroscopy, lifetimes...

So Far – It All Fits (damn!)



Current Constraints

- $B \rightarrow J/\psi K^0, \eta, \eta'$ β
- $B \rightarrow X_{c,u} l \nu$ $\alpha\text{-}\gamma$ side
- $B_{d,s}$ Mixing $\alpha\text{-}\beta$ side
- ϵ_K CPV

⇒ Consistent SM Picture

Future Constraints

- $B \rightarrow \phi K^0$ β
- $B_s \rightarrow J/\psi \phi$ β_s
- $B \rightarrow \pi\pi, \rho\rho$ α
- $B \rightarrow \pi K, K K, D K$ γ
- $K \rightarrow \pi \nu \nu$ V_{td}
- + many more!

⇒ There's still hope!



Fermilab & Flavor Physics

History

- Commissioned 1967
- Tevatron (p-pbar) 1983
- Main Injector 1999
- Run II Start 2001



Some Highlights

- b-quark discovery: 1977
 - * Lederman, et al
- t-quark discovery: 1994
 - * CDF & DØ
- ν_τ discovery: 2000
 - * DONUT

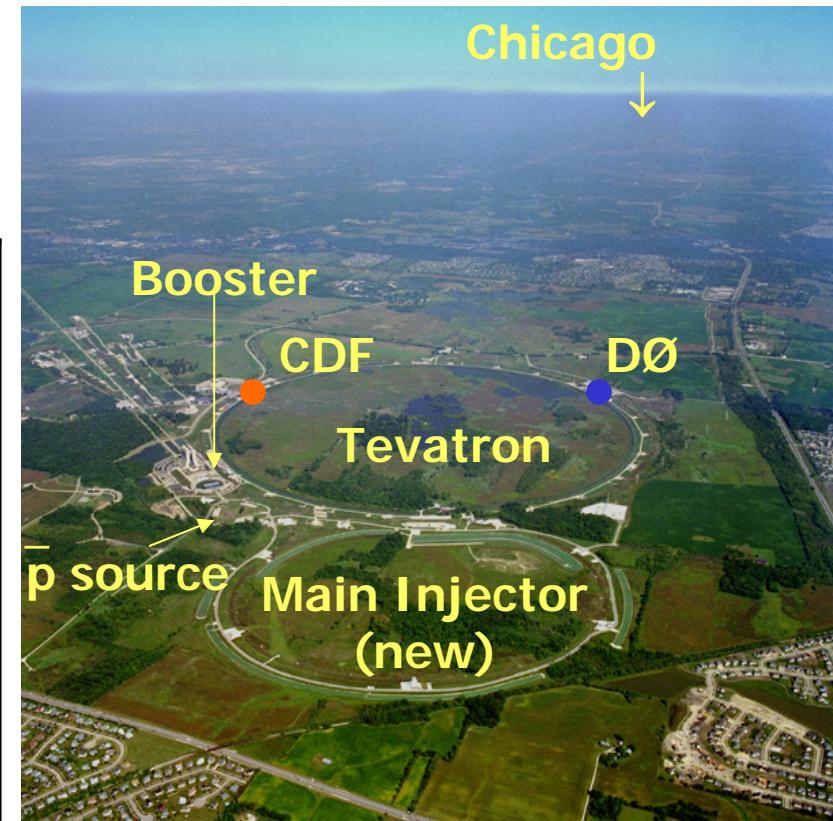


The Tevatron Collider

World's Highest E Accelerator

- ~4 miles circumference
- >1000 supercond. magnets

	Ib 92-96	IIa (now)	IIa (goal)
E-CM [GeV]	1800	1960	1960
Bunches	6x6	36x36	36x36
Spacing [ns]	3500	396	396
p/bch ($\times 10^{10}$)	23	22	27
Anti-p/bch ($\times 10^{10}$)	5.5	2.2	13
Peak Lumi. [$\text{cm}^{-2}\text{s}^{-1}$] ($\times 10^{31}$)	0.16	5	28
Lumi/week pb^{-1}	3.2	8	55
Tot Lumi fb^{-1}	0.125	0.305	9
Int's/X'ing	2.5	<1	>6





b's in their Natural Habitats

	Tevatron Run II	LEP	CLEO	B-Fact	LHC
Collisions	$p\bar{p}$	e^+e^-	e^+e^-	e^+e^-	pp
Ecm [GeV]	1960	91	10.5	10.5	14000
Species Prod	all	all	B_d, B^+	B_d, B^+	all
$\sigma(b\bar{b})$ [μb]	~100	0.007	0.001	0.001	~500
S/B [%]	0.1	0.15	~0.3	~0.3	0.6
In Accept. [%]	~6	~100	~100	~100	~5
Luminosity [$cm^{-2}s^{-1}$]	1×10^{32}	$\sim 10^{31}$	7.5×10^{32}	1×10^{34}	1×10^{33}
Rate w/o trig [Hz]	600	0.07	0.8	10	25,000
$\langle Decay L \rangle$ [mm]	0.45	3	0.025	0.26	1.7 (L_{xy})



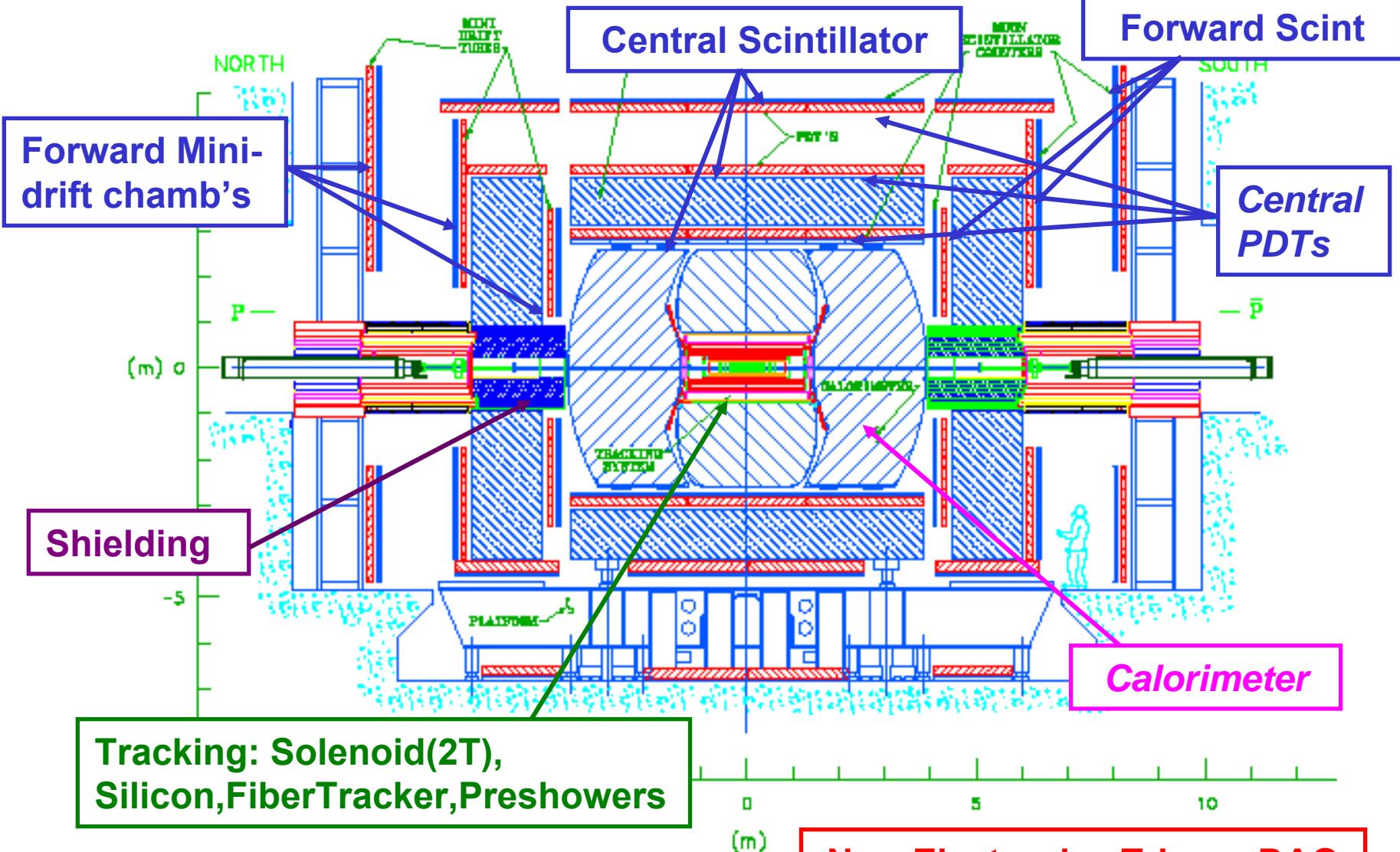
DØ Collaboration



**646 people
73 institutions
18 countries**



DØ Detector (the cartoon)



The Real McCoy !



- ~1M Channels
- 2.5M Event/s
- 250 KB/Event



DØ à la carte

**DØ is a General Purpose Detector
Designed to Study a Huge Range of Physics Topics**

QCD	<ul style="list-style-type: none">• Understand the strong force where it is predictive• Background for all other physics
B Physics	<ul style="list-style-type: none">• QCD at perturb/non-perturb interface• Probe quark mixing• Indirect evidence for new physics
W/Z	<ul style="list-style-type: none">• QCD Tests• Precision measurement of EW parameters
Top	<ul style="list-style-type: none">• Precision measurement of EW parameters• Most massive particle ⇒ new physics
Higgs	<ul style="list-style-type: none">• The heart of EW symmetry breaking
Searches	<ul style="list-style-type: none">• Directly look for new particles/effects predicted by specific beyond the SM models



B Measurements to Watch

- Confidence Builders
– Lifetimes
– B_d Mixing
 - b-Production
– b-production x-section & correlations
– J/ψ & Υ production mechanisms
 - b-Spectroscopy
– X, B_s, B_c, B -Baryons
 - Rare Decays
– $B \rightarrow \mu^+ \mu^- / \mu^+ \mu^- K^*$
 - CP Violation
– $\sin(2\beta)$ from $B \rightarrow J/\psi K^0_s$
 - Mixing
– B_s Mixing

needed for other meas's
resolve previous discrep's
only place to see these
sensitive to beyond SM
competitive w/ B-Fact's
big impact on CKM fits

Theoretically Clean

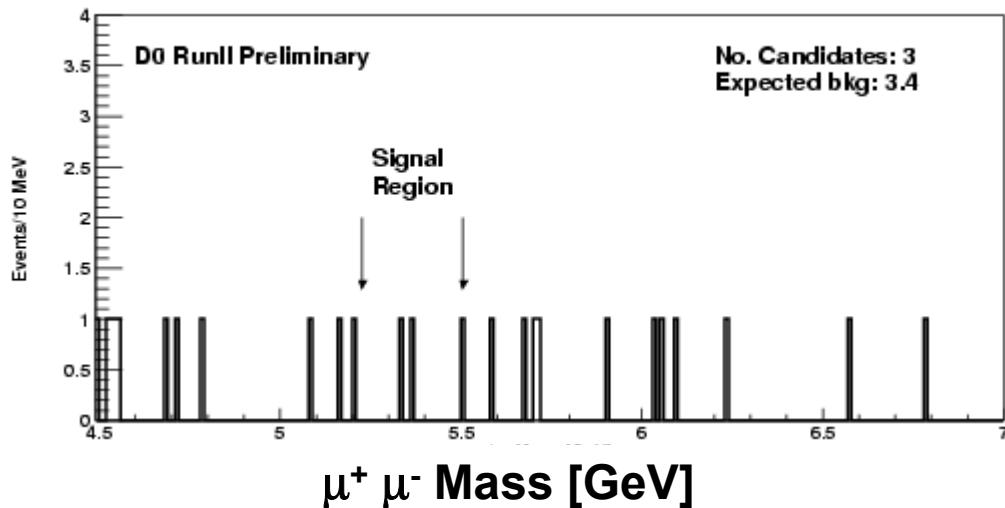
- FCNC B^0 decays forbidden at tree level in SM
- Can be large beyond SM

$$-\quad \Gamma_{2HDM} \propto \Gamma_{SM} \left(\frac{m_b \tan\beta}{M_W} \right)^2$$

Plays to DØ's Strengths

- Leptonic Triggering
- Event Reconstruction
 - $\mu^+ \mu^-$
 - * B mass, vertexing, isol.
 - $\mu^+ \mu^- K^*$
 - * K^* ID, no ψ resonances

Mode	BR(B_d)	BR(B_s)
$\mu^+ \mu^-$	1×10^{-10}	4×10^{-9}
$\mu^+ \mu^- K^* (\phi)$	1.5×10^{-6}	1×10^{-6}
$\mu^+ \mu^- X_s$		6×10^{-6}
$K^* \gamma$	4.4×10^{-5}	



Preliminary Limit
 $BR(B_s \rightarrow \mu^+ \mu^-) < 1.6 \times 10^{-6}$ (90% CL)

B Mixing

Weak \neq Mass Eigenstates
 \Rightarrow Neutral B's can mix

$$i \frac{d}{dt} \begin{pmatrix} |B(t)\rangle \\ |\bar{B}(t)\rangle \end{pmatrix} = \left(M - i \frac{\Gamma}{2} \right) \begin{pmatrix} |B(t)\rangle \\ |\bar{B}(t)\rangle \end{pmatrix}$$

M, Γ = Hermitian 2x2 matrices

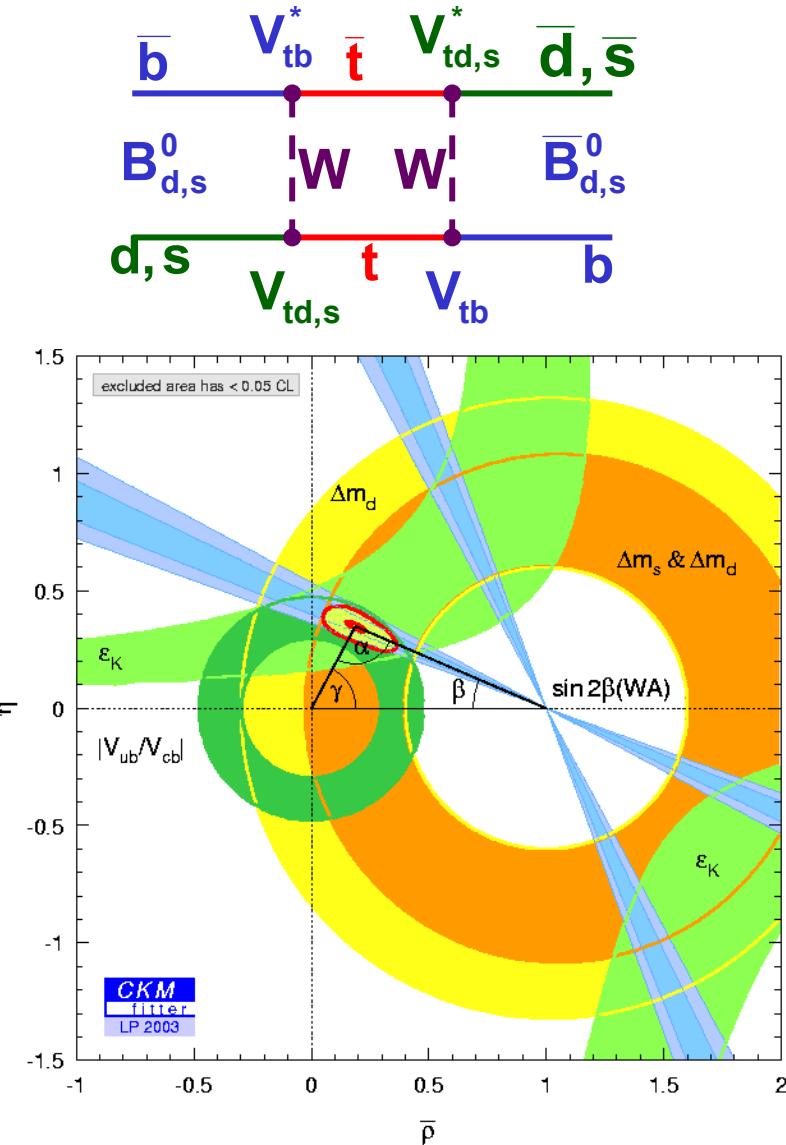
Time Evolution

$$P(B_q^0 \rightarrow B_q^0)(t) \propto e^{-\Gamma_q t} [1 + \cos(\Delta m_q t)]$$

$$P(B_q^0 \rightarrow \bar{B}_q^0)(t) \propto e^{-\Gamma_q t} [1 - \cos(\Delta m_q t)]$$

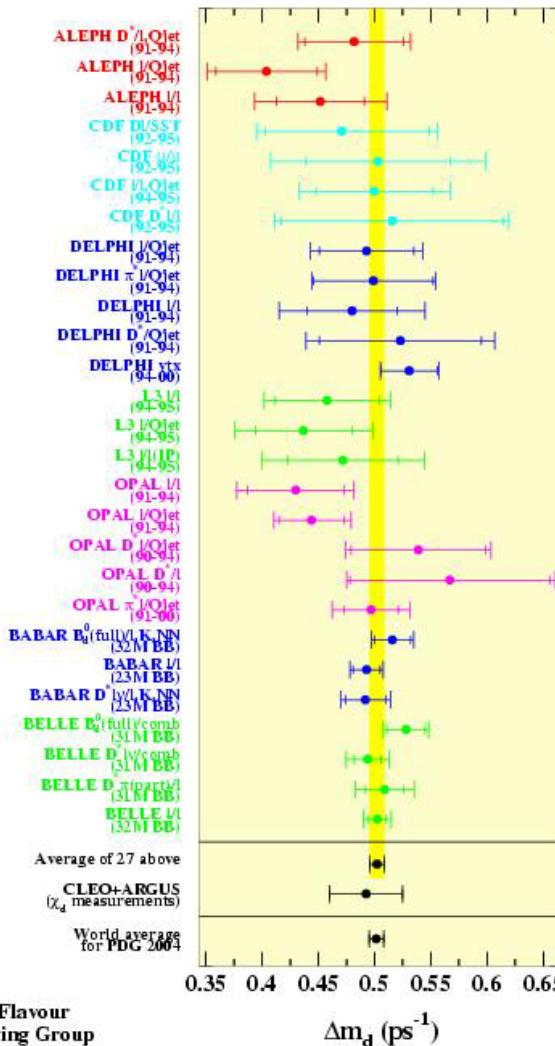
Sensitive to $|V_{td}|$ (side of triang.)

$$\frac{|V_{td}|}{|V_{ts}|} = \frac{F_{Bs} \sqrt{\hat{B}_{Bs}}}{F_{Bd} \sqrt{\hat{B}_{Bd}}} \sqrt{\frac{m_{Bs}}{m_{Bd}}} \sqrt{\frac{\Delta m_d}{\Delta m_s}}$$

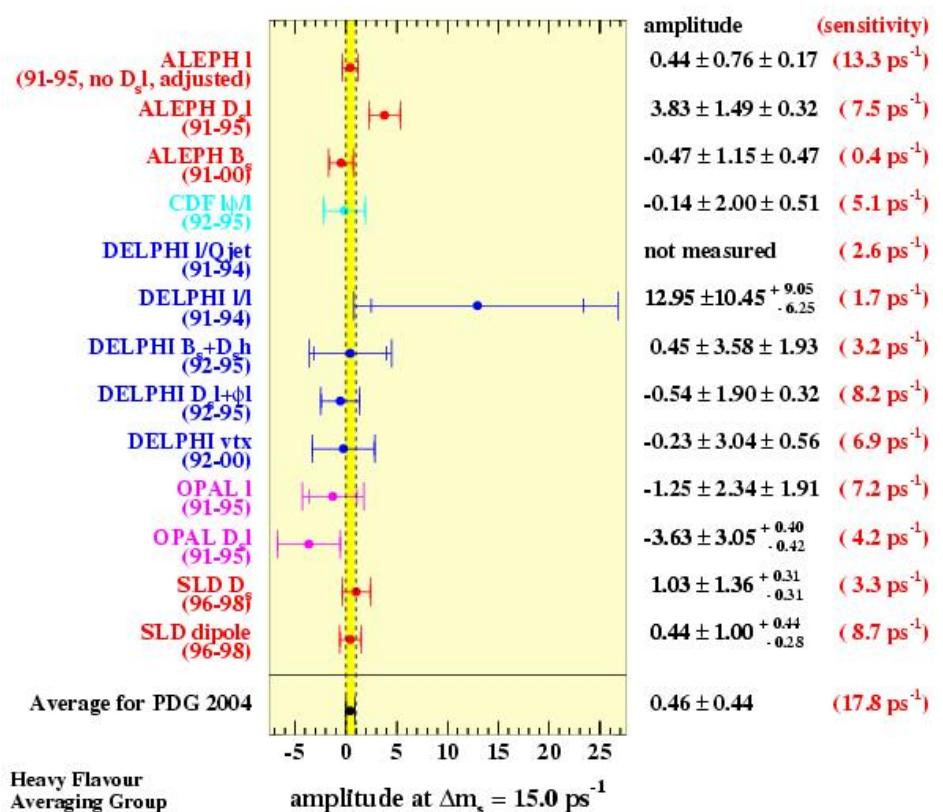


Mixing Now !

$$\Delta m_d = 0.502 \pm 0.007 \text{ ps}^{-1}$$

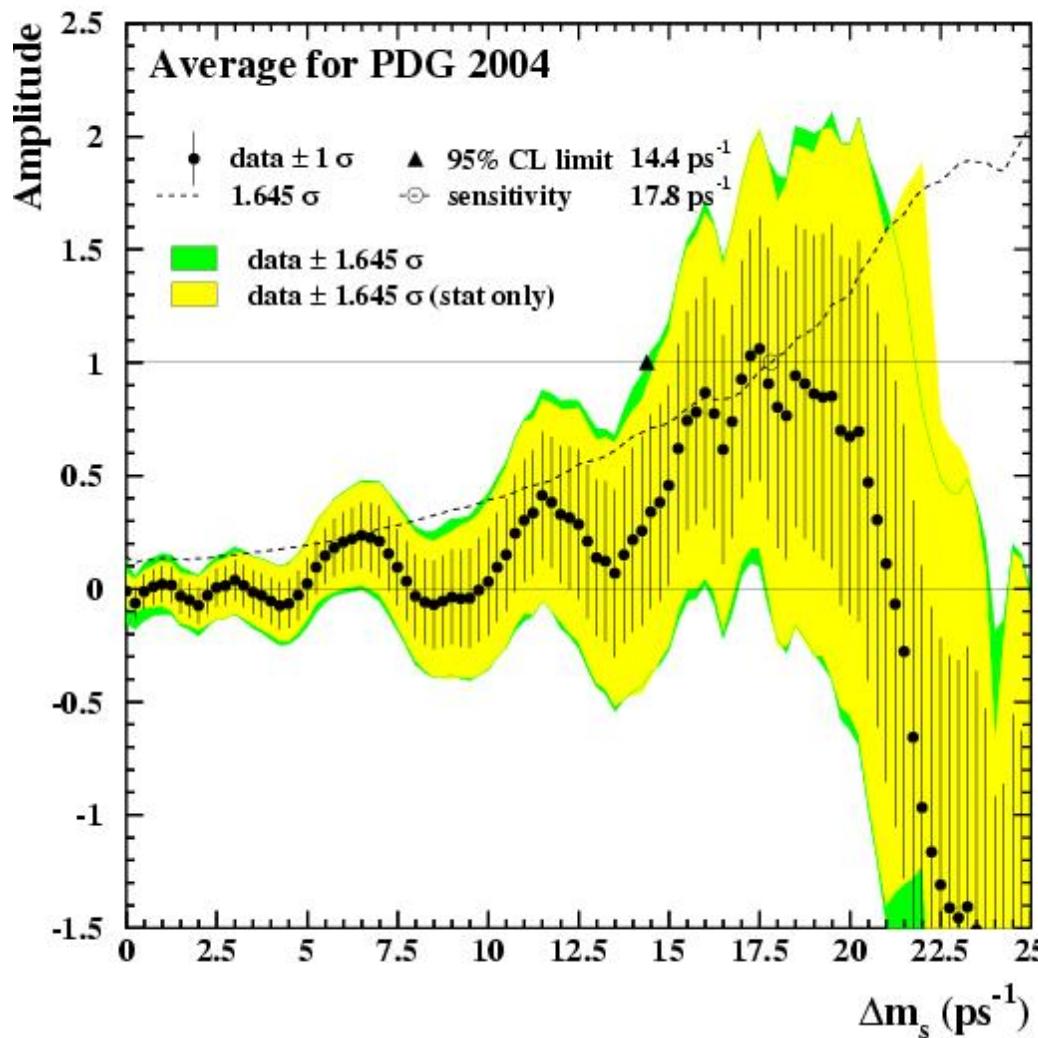


$$\Delta m_s > 14.4 \text{ ps}^{-1} (95\% \text{ CL})$$



Heavy Flavour Averaging Group
PDG 2004 update

Some Hints ?



SM Preferred Region:
~ $15 - 24 \text{ ps}^{-1}$ ("95%" CL)



Anatomy of a B_s Mixing Analysis

1. Identify B_s Candidates

- produce them
- get them to tape
- reconstruct them

2. Determine Proper Time

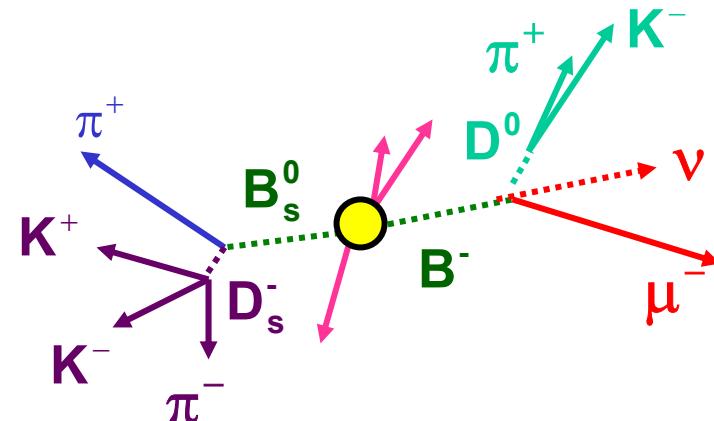
- decay length
- $ct = L / \gamma\beta$

3. Mixed or Unmixed

- flavor at production
- flavor at decay

4. Fit for Δm_s

- or ampl at Δm_s



Sensitivity

$$\langle \text{Signif} \rangle = \sqrt{\frac{N\varepsilon D^2}{2}} \sqrt{\frac{S}{S+B}} \times e^{-(\Delta m_s \sigma_t)^2/2}$$

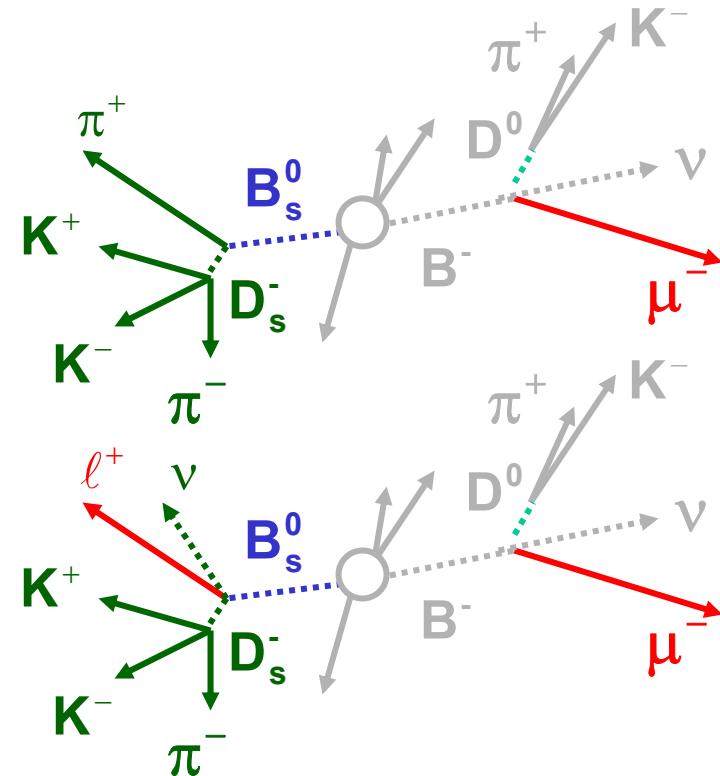
- N = no. of B_s candidates
- ε = frac. of B_s in N
- D = $1 - 2 \times \text{Prob}(\text{mistag})$
- S/B = signal/ bgrd in N
- σ_t = ave. proper time res.

Finding the Elusive B_s

1. Produce a B_s
 - $f_s \sim 0.1$ vs. $f_d = f_u \sim 0.4$

2. Trigger on the Event
 - L1 is the bottleneck
 - Di- μ ($P_t > 3$, $|\eta| < 2.2$) no presc.
 - Di- μ ($P_t > 1.5$, $|\eta| < 2.2$) prescale
 - 1- μ ($P_t > 3-5$, $|\eta| < 2.2$) prescale

3. Reconstruct B_s
 - $D_s^{(*)} / \nu$ BR $\sim 10\%$
 - * more stat's
 - * poorer σ_t
 - (can trigger on lepton)
 - $D_s^{(*)} \pi$ BR $\sim 0.5\%$
 - * less stat's
 - better σ_t
 - $D_s \rightarrow \phi \pi, \phi/\nu$ ($\phi \rightarrow K K$)



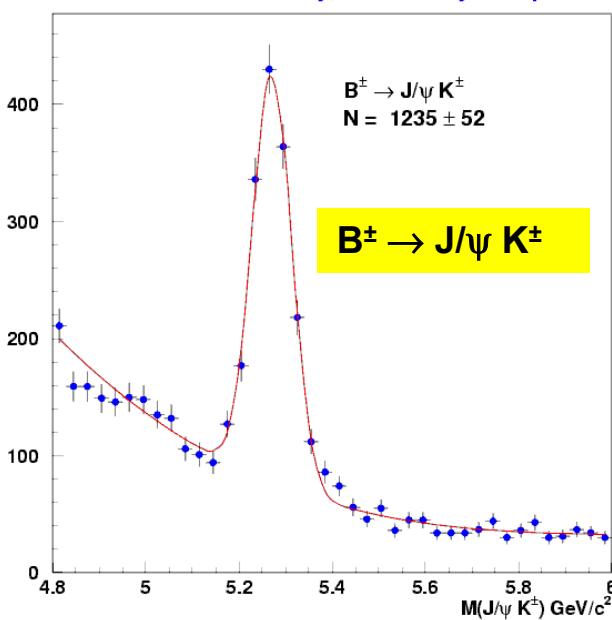
Experimental Challenges

- 20–40% of B_s out of accept when trigger on opp. lepton
- Low P_t trigger lepton
- Low P_t tracks

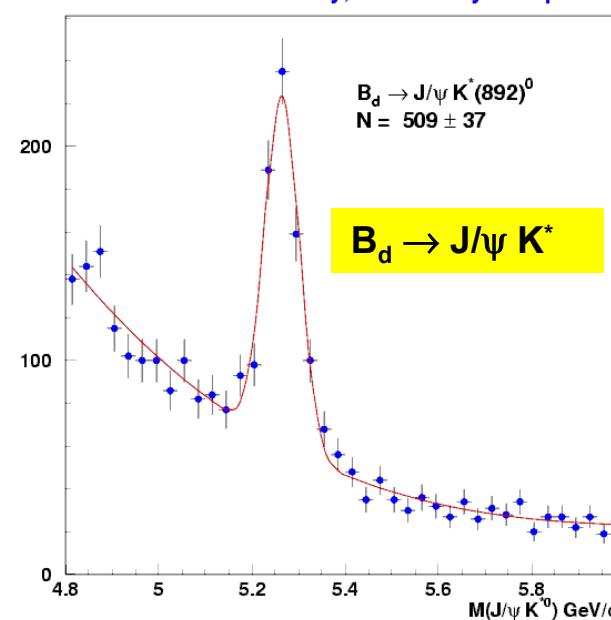


We Reconstruct B's !

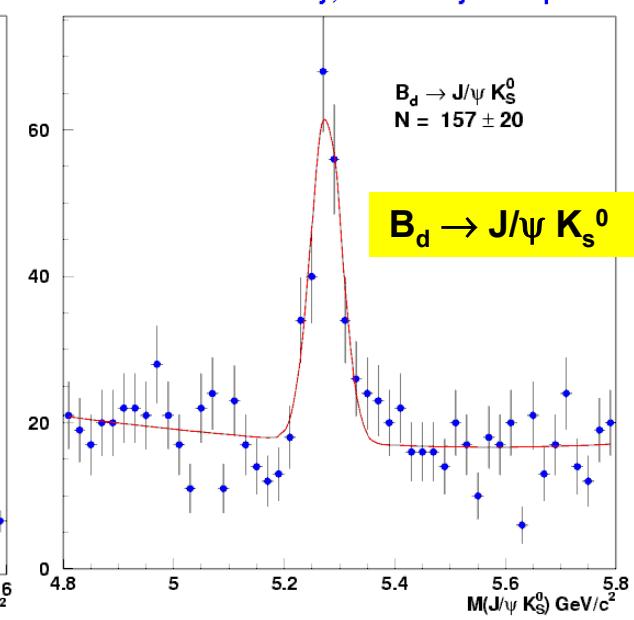
D0 RunII Preliminary, Luminosity=114 pb⁻¹



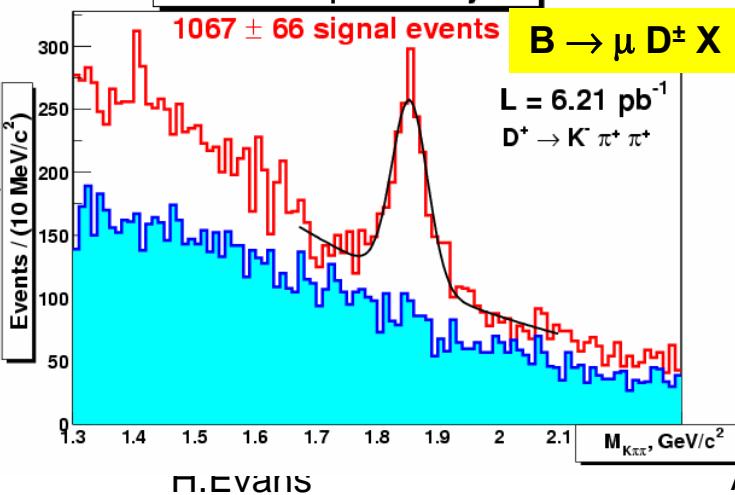
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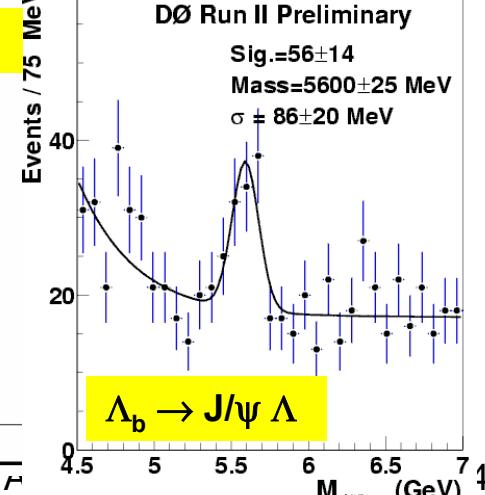
D0 RunII Preliminary, Luminosity = 114 pb⁻¹



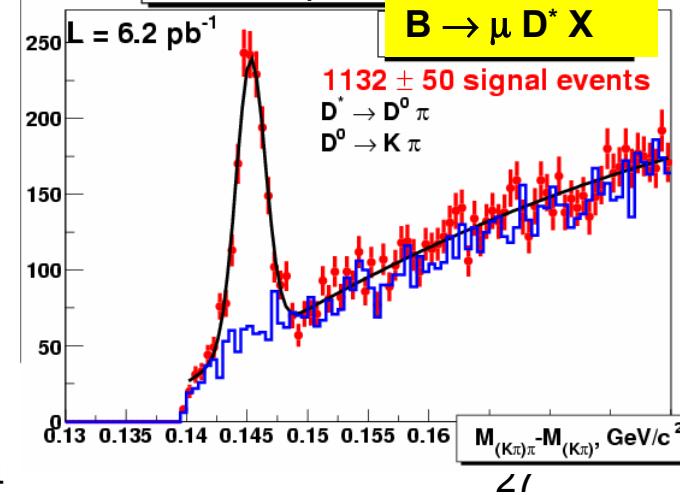
D0 RunII preliminary



D0 Run II Preliminary



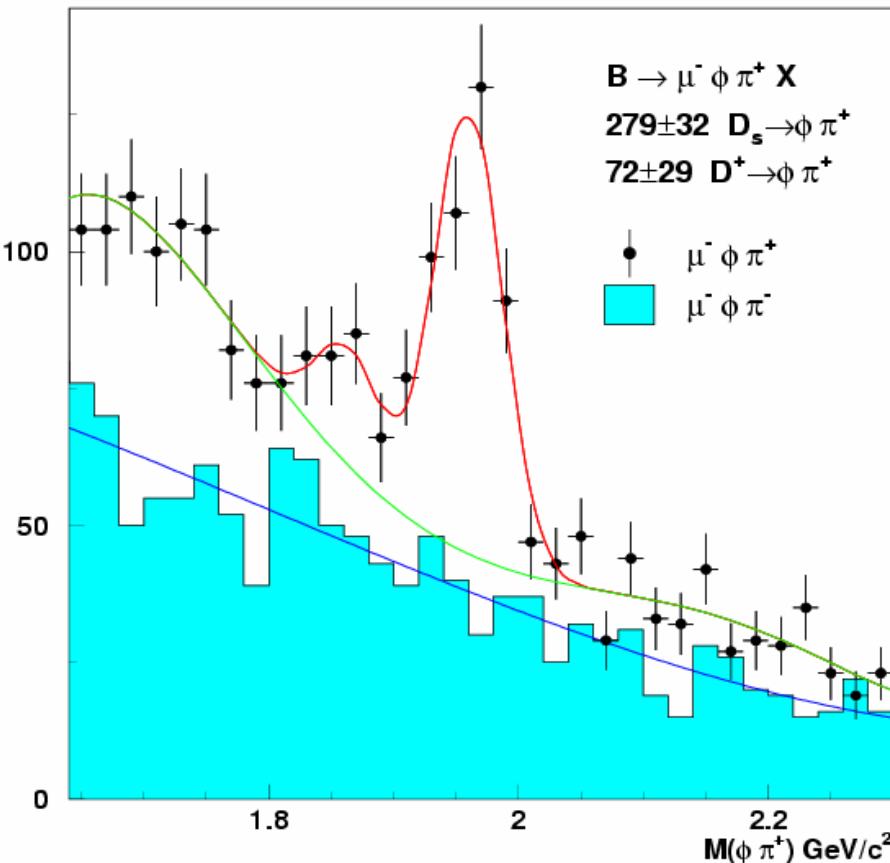
D0 RunII preliminary



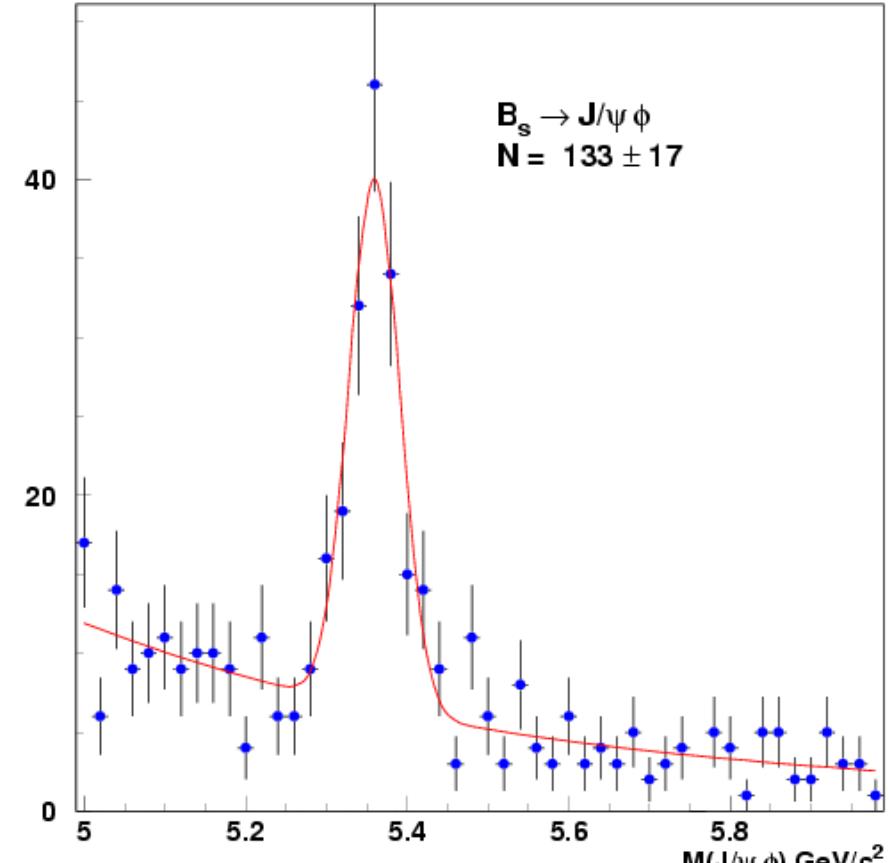


...And Even B_s

D0 RunII Preliminary, Luminosity = 6.2 pb^{-1}



D0 RunII Preliminary, Luminosity= 114 pb^{-1}

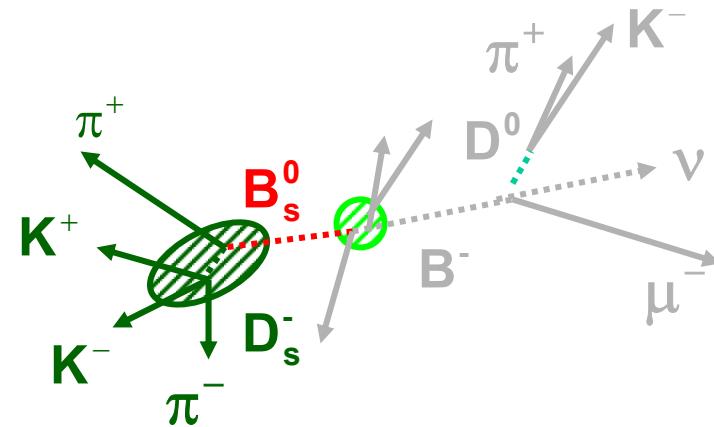




How Long Does It Live ?

1. Estimate Decay Length (L_{xy})

- Beam Spot
 - * size $\sim 35 \mu\text{m}$ in x-y
 - * average vs. evt-by-evt
- B_s Decay Point
 - * vertexing
- Decay Length Error (σ_L)



2. Estimate B Momentum

- $ct = L / \gamma\beta$
- $B_s \rightarrow D_s^{(*)} \pi$ very precise
- $B_s \rightarrow D_s^{(*)} / \nu$ missing ν
- must use MC to est. corr.

3. Proper Time & Error

$$ct = L_{xy} \left(\frac{M_B}{P_t^{\text{meas}}} \right) K$$

$$\left(\frac{\sigma_t}{\tau_B} \right)^2 = \left(\frac{\sigma_L}{L_B^0} \right)^2 + \left(\frac{t}{\tau_B} \frac{\sigma_K}{K} \right)^2$$

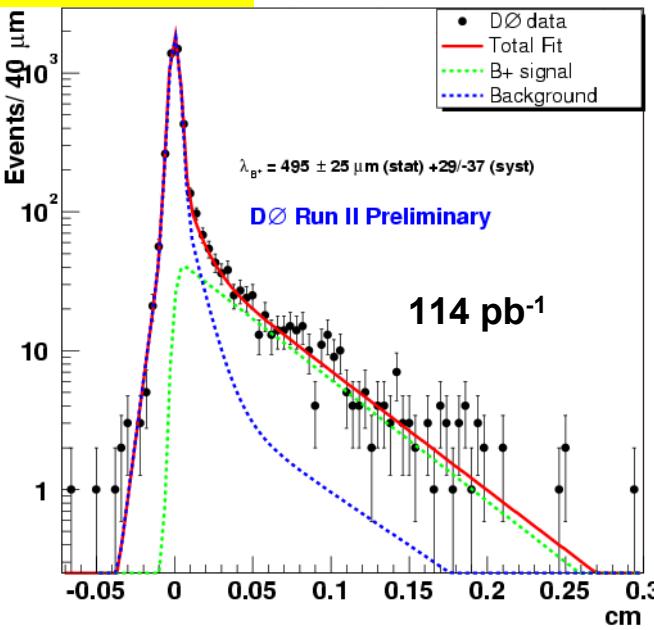
Experimental Challenge

- understand resolution

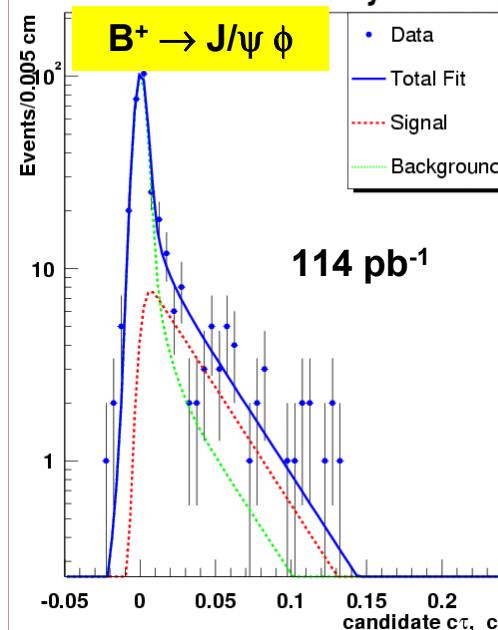


Study Resolution with Lifetimes

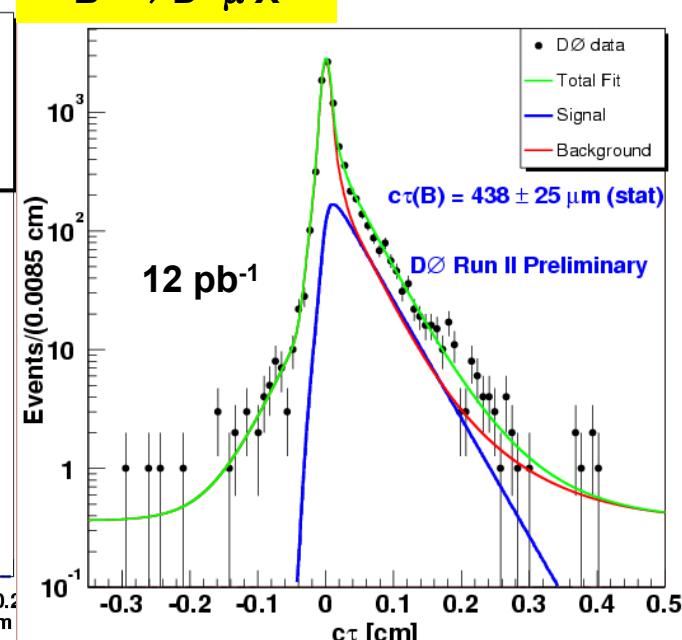
$B^+ \rightarrow J/\psi K^+$



DO Run II Preliminary



$B^+ \rightarrow D^0 \mu X$



Mode	Lifetime (stat,syst) [ps]	PDG Ave. [ps]	Resolution [fs]
$B \rightarrow J/\psi X$	$1.562 \pm 0.013 \pm 0.045$		~100
$B^+ \rightarrow J/\psi K^+$	$1.65 \pm 0.08 +0.09/-0.12$	1.674 ± 0.018	~100
$B_d \rightarrow J/\psi K^{*0}$	$1.51 +0.19/-0.17 \pm 0.20$	1.542 ± 0.016	~110
$B_s \rightarrow J/\psi \phi$	$1.19 +0.19/-0.16 \pm 0.14$	1.461 ± 0.057	~110
$B \rightarrow D^0 \mu X$	1.460 ± 0.083	1.60 ± 0.02	$200(67\%) / 450(33\%)$

1. Tag Flavor at Production using Opposite Side

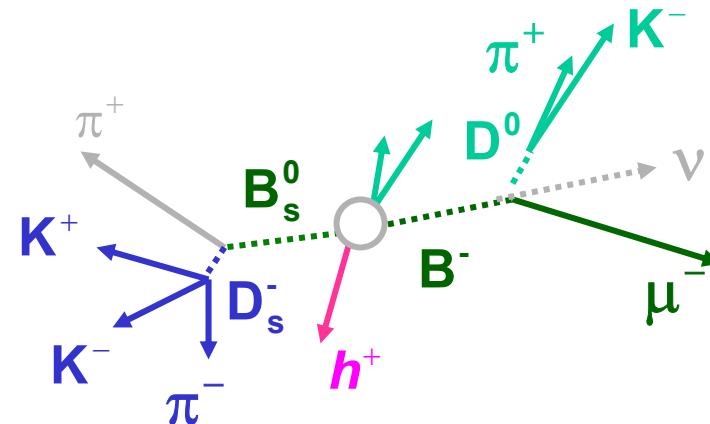
- Soft Lepton (muon) Tag
 - * μ -charge \Rightarrow b-charge
- Jet Charge Tag
 - * $\text{Jet } Q = \frac{\sum P_{t,i} q_i}{\sum P_{t,i}}$

2. Tag Flavor at Production using Same Side

- a. Charge of leading non- B_s hadron
 - * $B^{**} \rightarrow B h$ or fragmentation

3. Tag Flavor at Decay

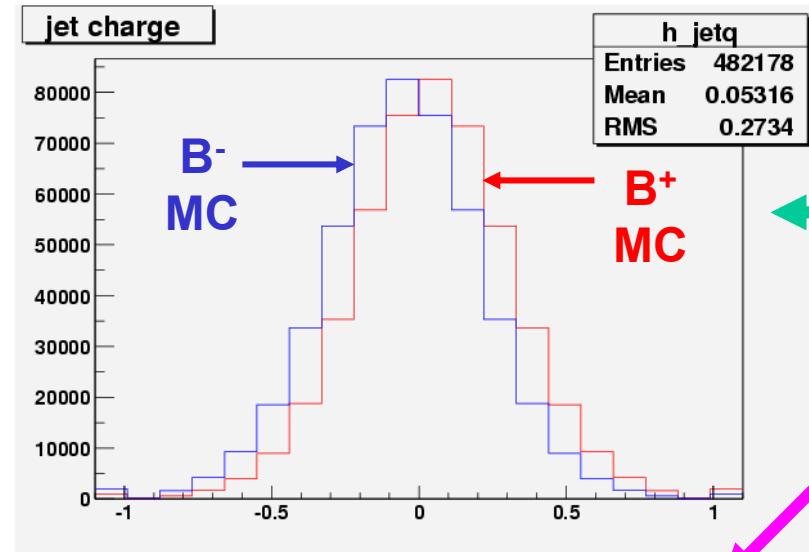
- D-charge \Rightarrow b-charge



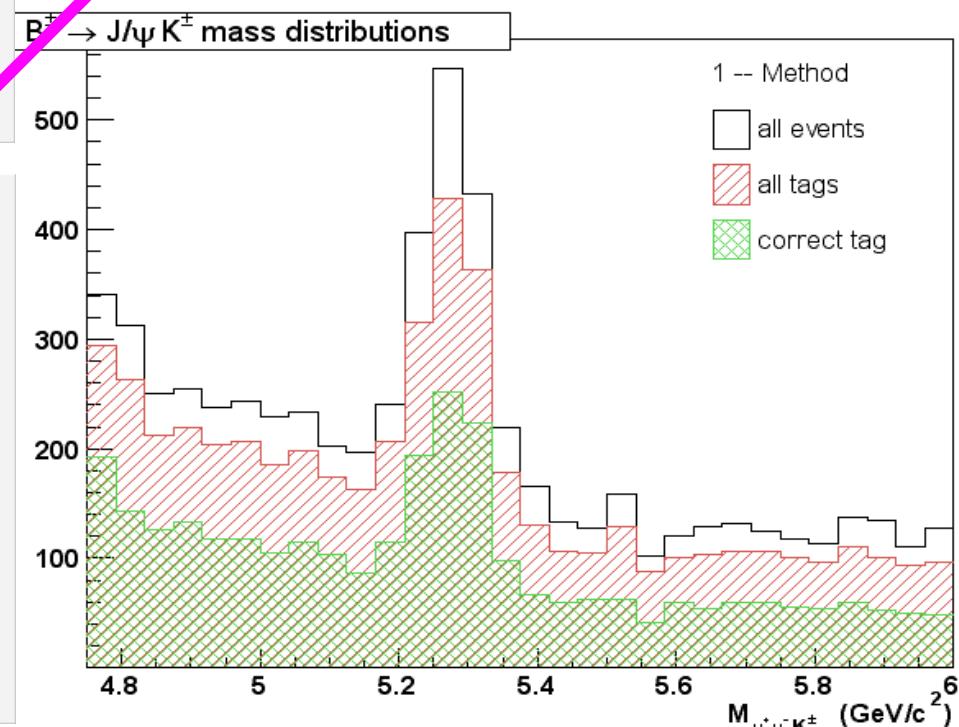
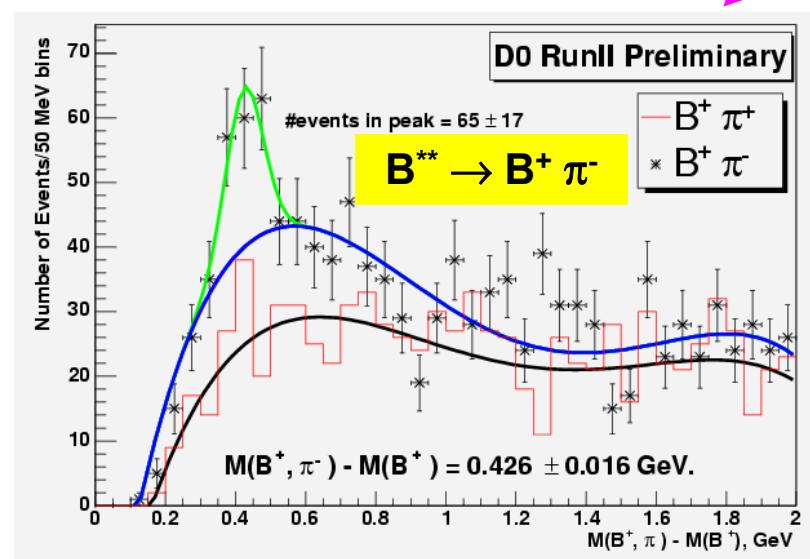
Experimental Challenge

- Measure mis-tag rate in Data
- $B^+ \rightarrow J/\psi K^+$ are a perfect lab

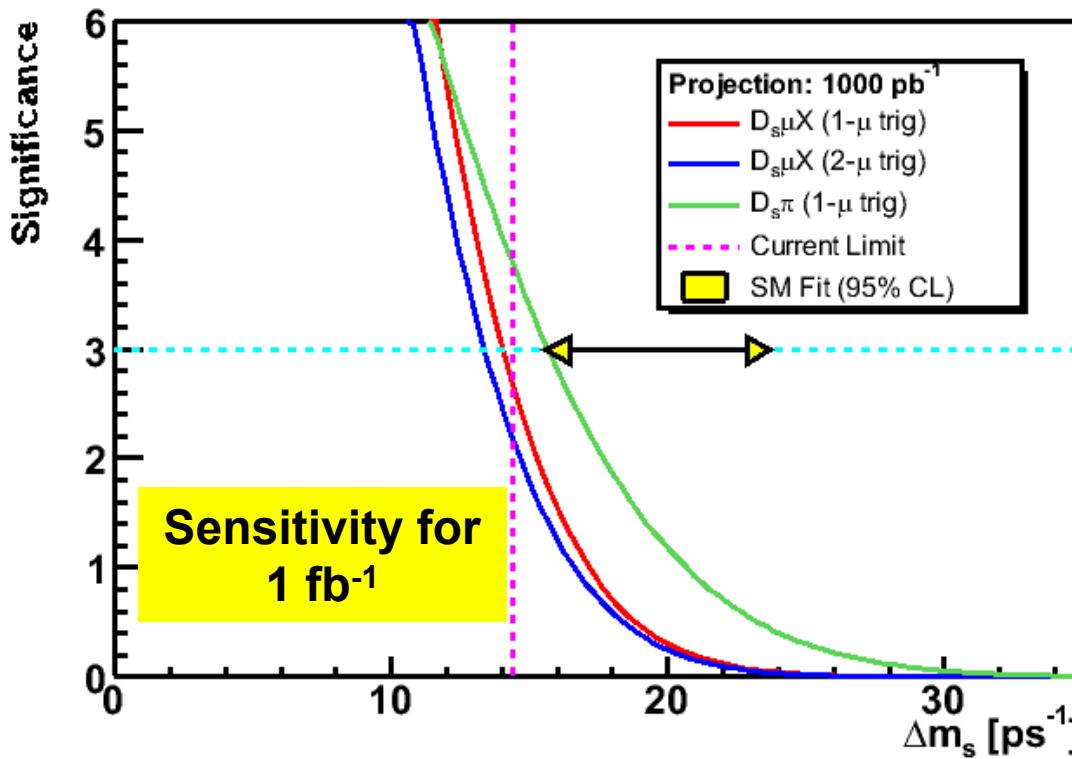
Controlling it with $B^+ \rightarrow J/\psi K^+$



Method	ϵ (%)	D (%)	ϵD^2 (%)
Soft Muon	5	57	1.6 ± 1.1
Jet Charge	47	27	3.3 ± 1.7
Same Side	79	26	5.5 ± 2.0



Nostradamus Predicts



- Add electron modes
 - Combine Results
- ⇒ Sensitivity to SM Fit Region



Mode	Trigger	Yield / pb^{-1}	εD^2 (%)	S/B	σ_t (fs)
$D_s^{(*)}\mu X$	1- μ	30	0.1	1	150
$D_s^{(*)}\mu X$	2- μ	4	0.5	1	150
$D_s^{(*)}\pi$	1- μ	1.4	0.5	1	110



DØ's Road Ahead

- Need to Establish B_s Mixing Measurement
 - systematic studies: tagging, resolution
 - Lifetimes & Δm_d measurements
- And Make Improvements
 - include electron modes
 - better resolution & momentum estimates
- But the Measurement is within Our Grasp !
- And That's Not All !
 - $\sin(2\beta)$ from $J/\psi K_s^0$ & $J/\psi \phi$
 - Rare Modes: $B_s \rightarrow \mu^+ \mu^-$ & $B_d \rightarrow \mu^+ \mu^- K^*$
 - Studies of the B_c & Λ_b
 - Precise measurements of production



Further Down the Path

	DØ,CDF	BaBar,Belle	BTeV	LHCb	Atlas,CMS
Beams	p \bar{p}	e ⁺ e ⁻	p \bar{p}	pp	pp
E _{CM} [TeV]	1.96	0.0106	1.96	14	14
Timeframe	now → 2009	now → 2005	2009	2007	2007
Inst Lumi ($\times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$)	0.4 → 2.8	100	2.0	2.0	100
Data Set [fb ⁻¹]	0.3 → 9	150 → 500	10 ¹¹ bb/yr	10 ¹² bb/yr	100/yr

Quantity	Mode	Curr. W.A.	Next Step	Improvement
V _{cb}	B → X _c /ν	(41.5 ± 1.1) × 10 ⁻³	theory	
V _{ub}	B → X _u /ν	(3.48 ± 0.54) × 10 ⁻³	theory	
Δm _s	B _s → D _s /νX, D _s π	> 14.4 ps ⁻¹	DØ,CDF BTeV,LHCb	~20-25 (5σ w/ 2 fb ⁻¹) ~50 (1 year)
sin 2β	B → J/ψ K ⁰	0.736 ± 0.049	DØ,CDF BaBar,Belle	± 0.03 (2 fb ⁻¹) ± 0.03 (0.5 ab ⁻¹)
γ	B → D _{CP} ⁰ K, Kπ	(95 ± 30)°	BaBar,Belle	± 14° (1.0 ab ⁻¹)
α	B → ππ, ρρ, ρρ	no dir. constr.	BTeV,LHCb	± 4° (1000 tag ρπ)
Rare	BR(B _s → μ ⁺ μ ⁻)	< 2 × 10 ⁻⁶	Atlas,CMS	(3.5 ± 0.8) × 10 ⁻⁹ (100 fb ⁻¹)



Conclusions

- **B-Hadrons provide a Sensitive Probe of EW Symmetry Breaking & Physics Beyond the SM**
 - allow classes of models to be favored/ruled out
 - complementary to direct searches for new particles
- **The DØ Experiment is Poised to make Major Contributions in the next few years**
 - QCD: lifetimes, spectroscopy, production...
 - CKM: B_s Mixing, $\sin 2\beta$, $\sin 2\beta_s$...
 - Rare: $B_s \rightarrow \mu^+ \mu^-$, $B \rightarrow K^* \mu^+ \mu^-$
- **Future Experiments will keep b's in our Bonnet for many years to come !**



Backup Slides



Stalking the Wild b-Quark

Mass (3rd Family)

$m_b \sim 4.5$ GeV

- couples to t-quark
- couples to New Physics
- perturbative QCD regime

Lifetime

$\tau \sim 1.6$ ps

Spectroscopy

- heavy-light mesons: B_u^\pm, B_d^0
- heavy-heavy mesons: B_c^\pm, B_s^0, Y
- baryons: $\Lambda_b^0, (\Xi, \Sigma, \Omega)$

Decays ~25 modes meas (B^0)

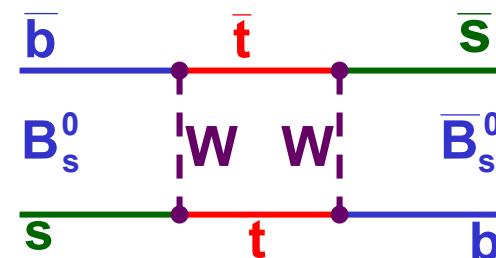
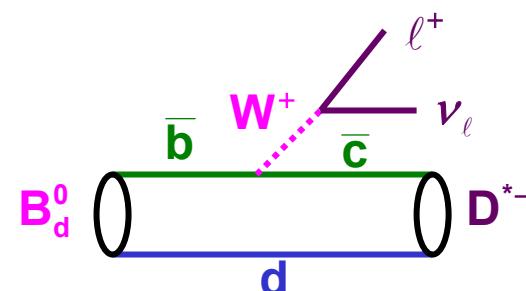
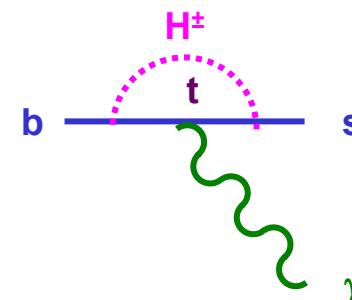
- 165 modes listed by PDG
- light quark spectator

Mixing

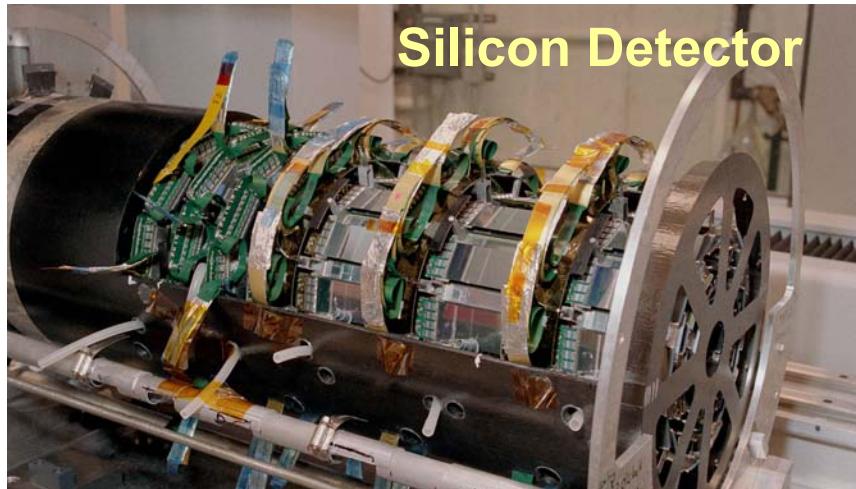
- $B^0 \leftrightarrow \bar{B}^0$ $\Delta m_d \sim 0.5$ ps⁻¹; $\Delta m_s > 14$ ps⁻¹

CP Violation

- $\Gamma(B) \neq \Gamma(\bar{B})$
- large effects (>10%) in some modes



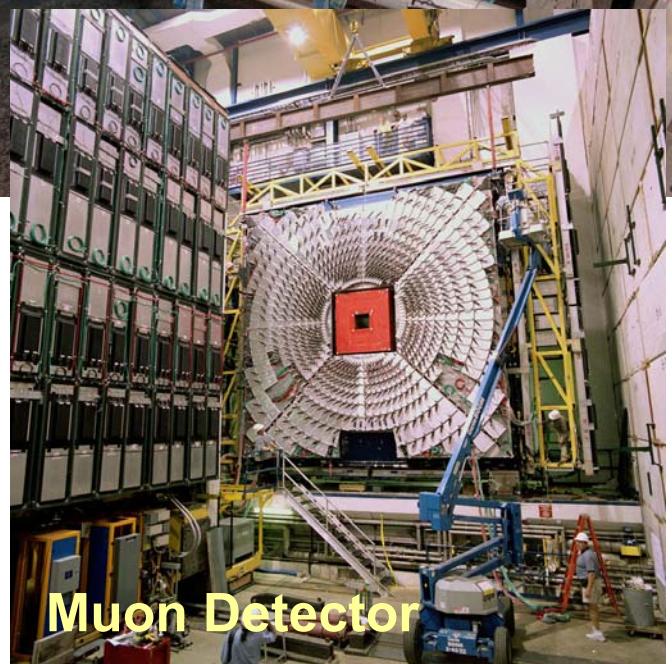
Some Pieces



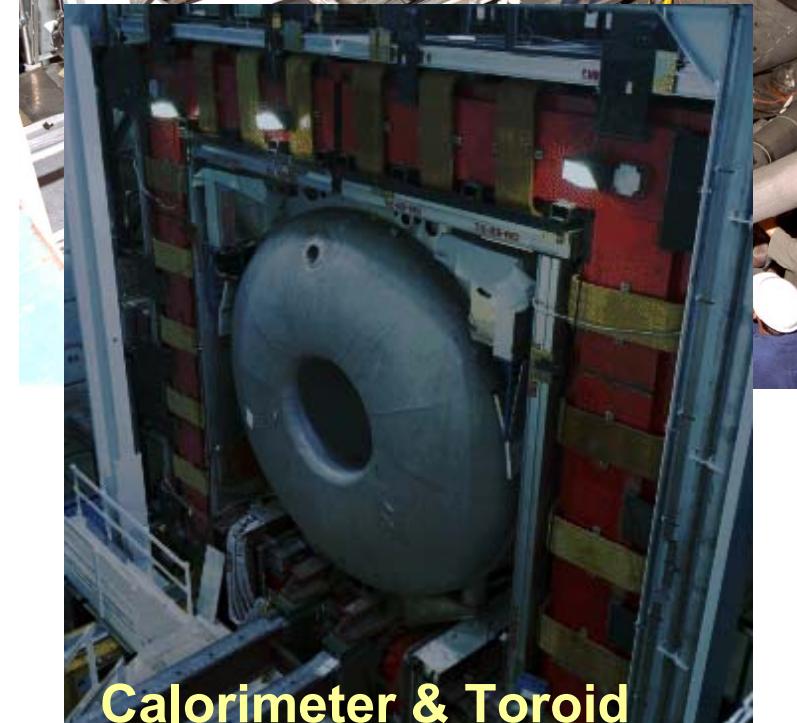
Silicon Detector



Fiber Tracker

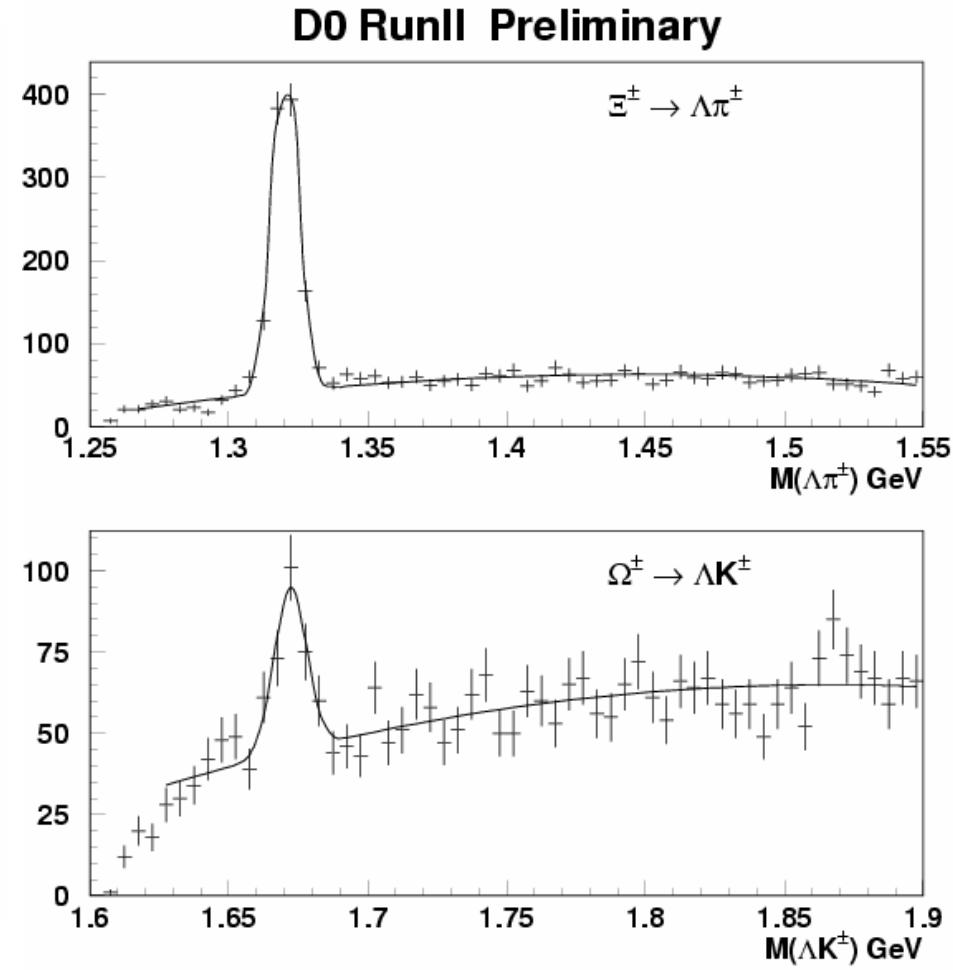
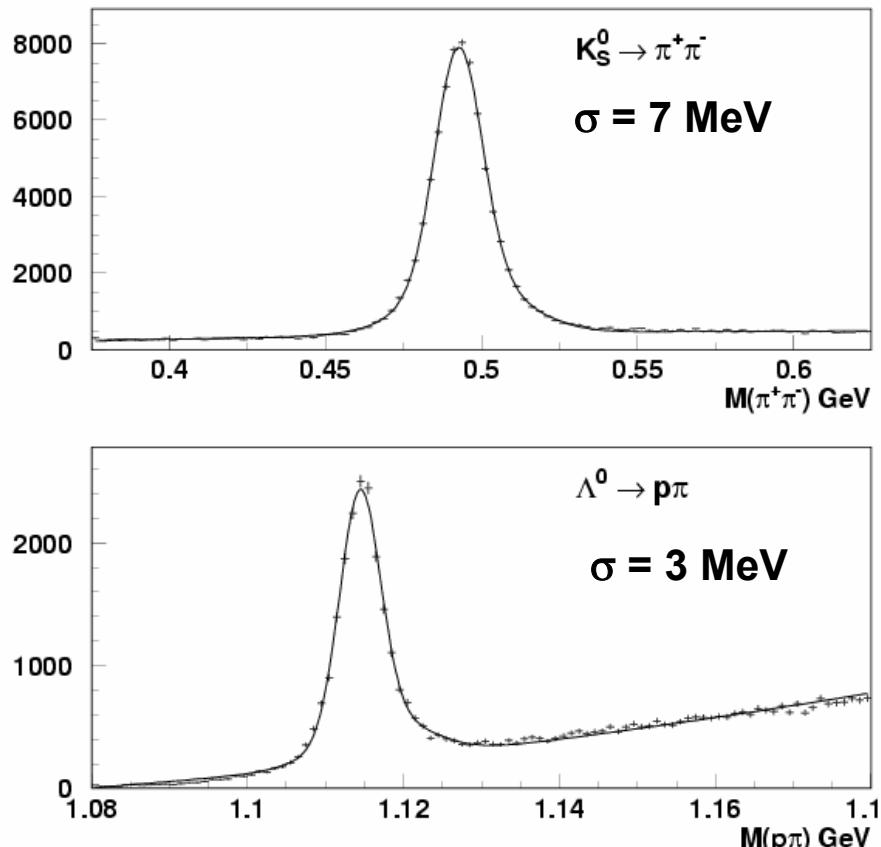


Muon Detector



Calorimeter & Toroid

Resonances





The J/ ψ

